01-28-00 A

CONTINUATION PATENT APPLICATION TRANSMITTAL

(filed under 37 C.F.R. §1.53(b))

Attorney Docket No.: 3123-149-1

Inventors: Naum V. Gitis of Cupertino, California
Victor Dunn of San Jose, California

Title: MAGNETIC HEAD SLIDER WITH RESISTANCE TO DEBRIS ACCUMULATION

Prior Group Art Unit: 2512

Prior Examiner: Korzuch, W.

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

This is a Continuation application of pending prior U.S. Application Serial No. 08/161,234, filed December 2, 1993, which is a continuation-in-part of U.S. Application Serial No. 07/992,270, filed December 14, 1992 (abandoned). The entire disclosure of the '270 application, from which a copy of the oath or declaration is supplied, is considered to be part of the disclosure of the accompanying application and is hereby incorporated by reference.

Enclosed for filing with the above-identified utility patent application, please find the following:

1. [X] Copy of the entire '270 application as originally filed, consisting of
   - Specification (12 pages)
   - Claims (2 pages)
   - Abstract (1 page)
   - Drawings (3 sheets) (informal)
2. [X] Copy of Declaration from the '270 application
3. [ ] Microfiche Computer Program (Appendix)
4. [ ] Assignment Papers *(cover sheet & document(s))*
5. [ ] Power of Attorney
6. [ ] Statement under 37 C.F.R. § 3.73(b) Establishing Right of Assignee to Take Action
7. [ ] Terminal Disclaimer
8. [ ] Submission of Proposed Drawing Amendment for Approval by Examiner
9. [X] Information Disclosure Statement (IDS/PTO-1449)
10. [ ] Copies of IDS Citations
11. [X] Preliminary Amendment
12. [X] Return Postcard (MPEP 503) *(should be specifically itemized)*
13. [ ] Small Entity Statement

FEE CALCULATION:

	(COL. 1) NO. FILED			(COL. 2) NO. EXTRA	LARGE ENTITY RATE	LARGE ENTITY FEE
BASIC FEE:						$690
TOTAL CLAIMS:	69	–	20	49	X $18 =	$882
INDEP. CLAIMS:	4	–	3	1	X $78 =	$78
MULTIPLE DEPENDENT CLAIMS: 0					+$260 =	$0
TOTAL						$1650

OTHER INFORMATION:

1. [X] The Commissioner is hereby authorized charge the $1650 filing fee and to debit any underpayment or credit any overpayment to Deposit Account No. 13-0016/149-1

2. [X] The Commissioner is hereby authorized to charge all required fees for extensions of time under 37 C.F.R. § 1.17 to Deposit Account No.13-0016/149-1

3. [X] The Power of Attorney appears in the '234 application.

4. [X] The '270 and '234 applications are assigned to Maxtor Corporation.

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EXPRESS MAIL MAILING LABEL NUMBER: EM544046591US

DATE OF DEPOSIT: JANUARY 26, 2000

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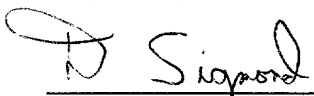
Respectfully submitted,



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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Gitis et al.		
Assignee:	Maxtor Corporation		
Title:	MAGNETIC HEAD SLIDER WITH RESISTANCE TO DEBRIS ACCUMULATION		
Serial No.:	Unknown	Filed:	Herewith
Examiner:	Unknown	Group Art Unit:	Unknown
Atty. Docket No.:	3123-149-1		

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Dear Sir:

The captioned-application is a continuation of pending prior U.S. Application Serial No. 08/161,234, filed December 2, 1993, which is a continuation-in-part of U.S. Application Serial No. 07/992,270, filed December 14, 1992 (abandoned). The '234 application incorporated by reference the '270 application at page 12, lines 1-4. The captioned-application is based on and only contains subject matter disclosed in the '270 application. Therefore, the effective filing date for the captioned-application is December 14, 1992. Please amend the captioned-application, based on the '270 application, as follows.

In the Abstract

Page 15, line 3, delete "region".

Page 15, line 4, delete "region".

In the Specification

Page 2, line 3, insert

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Application Serial No. 08/161,234, filed December 2, 1993, which is a continuation-in-part of U.S. Application Serial No. 07/992,270, filed December 14, 1992 (abandoned).

--

Page 2, line 21, change "μ" to --microns--.

Page 4, line 4, delete "4,709,274;".

Page 8, line 7, delete "region".

Page 9, line 13, after the second instance of "of" insert --the--.

Page 9, line 25, change "face" to --faces--.

Page 10, line 1, change the first instance of "is" to --it--.

Page 10, line 4, delete "that".

Page 10, line 8, after "height" insert --,--.

Page 11, line 2, change "are" to --is--.

Page 11, line 20, after the first and second instances of "in" insert --Figure--.

Page 11, line 25, delete "and".

In the Claims

Amend the following claims:

1. (Amended) A recording head for reading and writing information with respect to a rotating disk medium, said head including a pad [region] having a working surface which contacts said medium during the reading/writing process, a magnetic pole tip structure being embedded within said pad [region], said pad [region] having a leading edge and a trailing edge with said leading edge facing in the general direction of relative motion between said head and said medium, and wherein said leading edge has a narrower width than said trailing edge.

5. (Amended) A slider for supporting a magnetic transducer above the surface of a rotating disk medium, said slider comprising:

a body;

a plurality of rail members extending outward from said body in a direction towards said medium, each of said rail members having a leading and a trailing edge with said leading edge facing in the general direction of relative motion between said transducer [head] and said medium, and wherein said leading edge has a narrower width as compared to said trailing edge;

each of said rail members also having an air-bearing surface which is alternately brought into contact with and separated from said surface of said medium, said air-bearing surface being generally parallel to said surface of said medium.

8. (Amended) The slider [recording head] of Claim 5 wherein each of said rail members has a parabolic shape, with the narrow part of said parabolic shape pointing in said direction.

9. (Amended) The slider of Claim 5 wherein said leading edges are tapered away from said air-bearing surfaces [working surface] to create a lifting effect to maintain said body at a predetermined height above said surface of said medium.

Add the following claims:

10. A slider, comprising

a transducer for transferring information to and from a rotating disk medium during read and write operations; and

a pad which maintains substantially continuous contact with the medium during the read and write operations, wherein the pad has a leading edge that faces into a general direction of relative motion between the slider and the medium, the pad has a trailing edge that faces away from the direction, the leading edge has a width that is substantially perpendicular to the direction, the trailing edge has a width that is substantially perpendicular to the direction, and the width of the leading edge is substantially narrower than the width of the trailing edge.

11. The slider of Claim 10 wherein the pad includes a V-shaped portion, a narrow part of the V-shaped portion is the leading edge and a wide part of the V-shaped portion is spaced from the leading edge.

12. The slider of Claim 11 wherein the wide part of the V-shaped portion is the trailing edge.

13. The slider of Claim 11 wherein the wide part of the V-shaped portion is spaced from the trailing edge.

14. The slider of claim 10 wherein the pad includes a U-shaped portion, a narrow part of the U-shaped portion is the leading edge and a wide part of the U-shaped portion is spaced from the leading edge.

15. The slider of Claim 14 wherein the wide part of the U-shaped portion is the trailing edge.

16. The slider of Claim 14 wherein the wide part of the U-shaped portion is spaced from the trailing edge.

17. The slider of claim 10 wherein the pad includes a wedge-shaped portion, a narrow part of the wedge-shaped portion is the leading edge and a wide part of the wedge-shaped portion is spaced from the leading edge.

18. The slider of Claim 17 wherein the wide part of the wedge-shaped portion is the trailing edge.

19. The slider of Claim 17 wherein the wide part of the wedge-shaped portion is spaced from the trailing edge.

20. The slider of claim 10 wherein the pad includes a parabolic-shaped portion, a narrow part of the parabolic-shaped portion is the leading edge and a wide part of the parabolic-shaped portion is spaced from the leading edge.

21. The slider of Claim 20 wherein the wide part of the parabolic-shaped portion is the trailing edge.

22. The slider of Claim 20 wherein the wide part of the parabolic-shaped portion is spaced from the trailing edge.

23. The slider of claim 10 wherein the pad includes a hyperbolic-shaped portion, a narrow part of the hyperbolic-shaped portion is the leading edge and a wide part of the hyperbolic-shaped portion is spaced from the leading edge.

24. The slider of Claim 23 wherein the wide part of the hyperbolic-shaped portion is the trailing edge.

25. The slider of Claim 23 wherein the wide part of the hyperbolic-shaped portion is spaced from the trailing edge.

26. The slider of claim 10 wherein the pad has a single flat continuous surface that maintains the substantially continuous contact with the medium.

27. The slider of claim 10 wherein the slider has a leading edge that faces into the direction and a trailing edge that faces away from the direction, and the leading edge of the pad is spaced from the leading edge of the slider.

28. The slider of claim 27 wherein the trailing edge of the pad is the trailing edge of the slider.

29. The slider of claim 27 wherein the leading edge of the slider has a width that is substantially perpendicular to the direction, the trailing edge of the slider has a width that is substantially perpendicular to the direction, and the width of the leading edge of the slider is substantially identical to the width of the trailing edge of the slider.

30. The slider of claim 27 wherein a distance between the leading edge of the pad and the trailing edge of the slider is substantially less than a distance between the leading edge of the pad and the leading edge of the slider.

31. The slider of claim 10, wherein the slider has a leading edge that faces into the direction and a trailing edge that faces away from the direction, and the leading edge of the pad is the leading edge of the slider.

32. The slider of claim 31 wherein the trailing edge of the pad is the trailing edge of the slider.

33. The slider of claim 10 wherein the pad has a uniform thickness.

34. The slider of claim 10 wherein the slider has a uniform thickness.

35 The slider of claim 10 wherein the pad deflects debris away from an interface between the pad and the medium along sides of the pad during the read and write operations.

36. The slider of claim 10 wherein the pad maintains continuous contact with the medium during the read and write operations.

37. The slider of claim 10 wherein the pad maintains frequent contact with the medium during the read and write operations.

38. The slider of claim 10 wherein the pad maintains near-contact with the medium during the read and write operations.

39. The slider of claim 10 wherein the pad maintains a near-contact flying height in the range of 1 to 3 microinches during the read and write operations.

40. A slider, comprising

a transducer for transferring information to and from a rotating disk medium during read and write operations; and

first and second rails, wherein each of the rails has a leading edge that faces into a general direction of relative motion between the slider and the medium, a trailing edge that faces away from the direction, and an air-bearing surface, the leading edge has a width that is substantially perpendicular to the direction, the trailing edge has a width that is substantially perpendicular to the direction, and the width of the leading edge is substantially narrower than the width of the trailing edge.

41. The slider of Claim 40 wherein each of the rails includes a V-shaped portion, a narrow part of the V-shaped portion is the leading edge and a wide part of the V-shaped portion is spaced from the leading edge.

42. The slider of Claim 41 wherein the wide part of the V-shaped portion is the trailing edge.

43. The slider of Claim 42 wherein a thickness of the narrow part of the V-shaped portion is substantially identical to a thickness of the wide part of the V-shaped portion.

44. The slider of Claim 42 wherein a thickness of the narrow part of the V-shaped portion is substantially less than a thickness of the wide part of the V-shaped portion.

45. The slider of Claim 41 wherein the wide part of the V-shaped portion is spaced from the trailing edge.

46. The slider of Claim 45 wherein a distance between the narrow part of the V-shaped portion and the wide part of the V-shaped portion is substantially less than a distance between the wide part of the V-shaped portion and the trailing edge.

47. The slider of claim 40 wherein each of the rails includes a U-shaped portion, a narrow part of the U-shaped portion is the leading edge and a wide part of the U-shaped portion is spaced from the leading edge.

48. The slider of Claim 47 wherein the wide part of the U-shaped portion is spaced from the trailing edge.

49. The slider of Claim 47 wherein each of the rails includes a rectilinear portion between the U-shaped portion and the trailing edge.

50. The slider of claim 40 wherein each of the rails includes a wedge-shaped portion, a narrow part of the wedge-shaped portion is the leading edge and a wide part of the wedge-shaped portion is spaced from the leading edge.

51. The slider of Claim 50 wherein the wide part of the wedge-shaped portion is spaced from the trailing edge.

52. The slider of Claim 50 wherein each of the rails includes a rectilinear portion between the wedge-shaped portion and the trailing edge, and the narrow part of the wedge-shaped portion is aligned with an inner side of the rectilinear portion and spaced from an outer side of the rectilinear portion.

53. The slider of claim 40 wherein each of the rails includes a parabolic-shaped portion, a narrow part of the parabolic-shaped portion is the leading edge and a wide part of the parabolic-shaped portion is spaced from the leading edge.

54. The slider of Claim 53 wherein the wide part of the parabolic-shaped portion is spaced from the trailing edge.

55. The slider of Claim 53 wherein each of the rails includes a rectilinear portion between the parabolic-shaped portion and the trailing edge.

56. The slider of claim 40 wherein each of the rails has a hyperbolic-shaped portion, a narrow part of the hyperbolic-shaped portion is the leading edge and a wide part of the hyperbolic-shaped portion is spaced from the leading edge.

57. The slider of Claim 56 wherein the wide part of the hyperbolic-shaped portion is spaced from the trailing edge.

58. The slider of Claim 56 wherein each of the rails includes a rectilinear portion between the hyperbolic-shaped portion and the trailing edge.

59. The slider of claim 40 wherein the air-bearing surface is a flat continuous surface that maintains substantially continuous contact with the medium.

60. The slider of claim 40 wherein the slider has a leading edge that faces into the direction and a trailing edge that faces away from the direction, the leading edge of each of the rails extends to the leading edge of the slider, and the trailing edge of each of the rails extends to the trailing edge of the slider.

61. The slider of claim 40 wherein the slider has first and second outer side surfaces, each of the rails has an outer side surface, a portion of the outer side surface of the first rail extends to the first outer side surface of the slider, and a portion of the outer side surface of the second rail extends to the second outer side surface of the slider.

62. The slider of claim 40 wherein each of the rails has an inner and outer surface and the leading edge is symmetrically disposed between the inner and outer surfaces.

63. The slider of claim 40 wherein each of the rails has an inner surface and outer surface and the leading edge is asymmetrically disposed between the inner and outer surfaces.

64. The slider of claim 40 wherein each of the rails has a uniform thickness.

65. The slider of claim 40 wherein each of the rails has a non-uniform thickness.

66. The slider of claim 40 wherein each of the rails deflects debris on the medium away from the air-bearing surface.

67. The slider of claim 40 wherein each of the rails maintains frequent contact with the medium during the read and write operations.

68. The slider of claim 40 wherein each of the rails maintains near-contact with the medium during the read and write operations.

69. The slider of claim 40 wherein each of the rails maintains a near-contact flying height in the range of 1 to 3 microinches during the read and write operations.

REMARKS

Claims 1-69 are pending. In this Preliminary Amendment, the abstract, specification and claims have been amended to improve clarity, and claims 10-69 have been added to further explicate and clarify various features of the invention. No new matter has been added.

In the '270 application, the Office Action dated September 15, 1993, rejected claim 1 under 35 U.S.C. § 102(b) as being anticipated by *Hamilton* (U.S. Patent No. 5,041,932). In sustaining this rejection, the Examiner stated the following:

> Hamilton shows in figure 1 a recording head 20 for reading and writing information with respect to a rotating disk medium. The head includes a pad region 22 having a working surface which contacts said medium during the reading/writing process, a magnetic pole embedded within said pad region (numeral 22 in figure 2), said pad region having a leading edge and a trailing edge with said leading edge facing in the general direction of relative motion between said head and said medium, and the leading edge has a narrower width than said trailing edge. (Pages 3-4.)

In *Hamilton*, read/write/head/flexure/conductor structure 20 includes main pole 22. Figure 1 is a working-side perspective (slightly rotated) which primarily shows the bottom side of structure 20, where A is the length, B is the width, C is a thickness, and D is a somewhat greater thicknesses. Figure 2 is an enlarged longitudinal lateral cross-section of the structure of Figure 1, and Figure 3 is a plan view generally taken from the bottom side of Figure 2. The pad region 22 the Examiner refers to appears to be the enlargement, with thickness D, which can be thought of as the read/write working end of the structure (col. 3, lines 35-39). As clearly seen in Figures 1 and 3, the read/write working end has leading and trailing edges with identical widths. Thus, the Examiner's assertion that the read/write working end has a leading edge with a narrower width than its trailing edge is completely unsupported.

The Office Action also rejected claim 2 under 35 U.S.C. § 103 as being unpatentable over *Hamilton* in view of *Verdone* (U.S. Patent No. 4,644,641). In sustaining this rejection, the Examiner stated the following:

> Hamilton shows all the features of claim 1 as shown above except for a pad with a V-shape. Verdone shows a figure 12A a pad with a V-shape that has a narrow part of said V-shape pointing in the general direction of relative motion between a head and a medium. It would have been obvious to one having ordinary skill in the art at the time the invention was made to provide the V-shaped pad of Verdone on the recording head of Hamilton. The rationale is as follows: One of ordinary skill in the art would have been motivated to use the V-shaped pad of Verdone in the recording head of Hamilton since it deflects dirt particles to either side of the slider which keeps the slider clean. (Pages 4-5.)

Hamilton discloses a read/write/head/flexure/conductor structure designed for continuous sliding contact with the recording medium:

> Specifically, an object of the invention is to provide a unique read/write structure which is orders of magnitude smaller in size and mass when compared with today's counterparts – a structure which is capable of non-catastrophic, continuous sliding contact interaction with the surface of a relatively moving recording medium. (Col. 2, lines 46-52.)
>
> The structures shown herein are so significantly reduced in size and mass, that experience has shown that they can be used for direct, continuous, sliding contact operation with a recording medium, virtually free from catastrophic wear. (Col. 5, lines 15-19.)
>
> The structure of the present invention can be used in direct, continuous contact with the surface of a relatively moving medium without any appreciable tendency to produce damaging wear. (Col. 8, lines 28-32.)

Verdone, on the other hand, discloses a delta slider designed to fly above the recording medium:

> A "Delta slider" for flying a magnetic head on a fluid bearing above moving magnetic recording medium is disclosed . . . (Col. 1, lines 5-7.)
>
> An object of this invention is to provide a novel and improved air bearing slider for a flying magnetic head assembly that maintains a substantially constant spacing relative to a moving magnetic medium during transducing operation. (Col. 1, lines 37-41.)
>
> Some novel features of this delta slider (ABS) appear to be:
> 1. CLEAN: A triangular or "Delta" shape (in plan-cross-section) together with a properly pitched flying attitude (leading edge flies at greater height than trailing edge above media) appears to give this design a particular self-cleaning aspect. Any dirt particles encountered (at the head-disk interface) will likely be deflected to either side of the slider. (Col. 8, lines 57-63.)

Thus, the read/write/head/flexure/conductor structure in *Hamilton* is designed for continuous sliding contact with the recording medium, whereas the delta slider in *Verdone* is designed for flying above the recording medium and provides self-cleaning as the leading edge flies at a greater height than the trailing edge. If the structure in *Hamilton* were modified in accordance with the delta slider in *Verdone*, then the structure in *Hamilton* would fly above the recording medium and be rendered unsatisfactory for its intended purpose.

If the proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification. See M.P.E.P. § 2143.01 (seventh edition, page 2100-112).

The Office Action also discussed other prior art:

> The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.
>
> Matsumoto is cited to show a V-shaped slider.
>
> Coughlin et al is cited to show a V-shaped portion of a slider in figure 1.

In *Matsumoto* (Japanese Patent No. 1-29858), the slider has a gas inflow end side 6 (the leading edge) and an outflow end side 7 (the trailing edge), however there is no teaching or suggestion that a pad (claim 1) or rail members (claim 5) have a leading edge with a narrower width than the trailing edge.

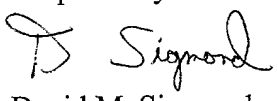
In *Coughlin* (U.S. Patent No. 4,700,248) the V-shaped section between slots 26 and 28 is neither a pad (claim 1) nor a rail member (claim 5). Furthermore, in the '234 application, the Decision by Board of Patent Appeals and Interferences dated September 22, 1999, provided the following remarks about *Coughlin* in reversing the rejection of claims 7 and 8:

> Dependent claim 7 recites that the load-bearing surface is tapered with its narrow end facing into the relative motion of the magnetic recording disk for the deflection of magnetic disk surface debris. Claim 8 depends from claim 7 and recites that the tapered surface has a uniform taper. The examiner relied upon Coughlin to teach those features of claims 7 and 8.
>
> Coughlin shows in Figures 1 and 2 a head assembly with a contoured load-bearing surface 20 with a pair of angled pressure relief slots 26 and 28 formed in the surface 20. It is the section formed between slots 26 and 28 that the examiner maintains is the tapered load bearing surface. We disagree. The entire contoured face 20, including the portions surrounding the angled slots, constitutes the load-bearing surface in Coughlin. Note that in column 4, lines 41-44 of Coughlin, it is stated: "It is this surface 20 of assembly 10 that is adapted to confront the rotating recording surface of the disk and interact with the air bearing layer to provide assembly 10 with its flying characteristics." Moreover, it is not seen how the tapered slots of Coughlin can be used to carry out their intended functions as the loud-bearing [sic] surface without

the presence of the load bearing surface portions surrounding them. In our view, the load bearing surface of Coughlin cannot reasonably be regarded as solely the portion between the slots. Accordingly, Coughlin's load bearing surface is not tapered "with its narrow end facing into the relative motion of the magnetic recording disk" as is recited in claim 7. Both ends appear to have the same width. In any event, even if it is assumed for purposes of argument that only the angled-slots section constitutes the load bearing surface, the presence of the outer portions of contour face 20 would seem to keep the tapered load bearing surface from being able to deflect surface debris as is recited in claim 7.

The captioned-application is believed to be in condition for allowance. Should any issues arise, the Examiner is encouraged to telephone the undersigned attorney.

Respectfully submitted,



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UNITED STATES PATENT APPLICATION

for

MAGNETIC HEAD SLIDER WITH RESISTANCE TO DEBRIS ACCUMULATION

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MAGNETIC HEAD SLIDER WITH RESISTANCE TO DEBRIS ACCUMULATION

FIELD OF THE INVENTION

This invention relates to the fields of magnetic recording and tribology. More specifically, the invention relates to the design of magnetic recording heads and sliders for primary use in near-contact and in-contact recording systems.

BACKGROUND OF THE INVENTION

Researchers working in the magnetic recording industry have recently begun focusing their efforts on developing thin film heads having a so-called integrated head/flexure/conductor structure for reading and writing of information to a disk medium. For example, such a magnetic head structure is disclosed in U.S. Patent No. 5,041,932. In this type of recording technology, a magnetic pole element is embedded within the body of the magnetic recording head. Advanced performance is achieved in these types of magnetic recording heads by including a contact pad region which is in non-catastrophic, continuous sliding contact with the surface of the recording medium. The contact pad includes a working surface portion which is extremely small -- on the order of about 20 X 30 μ. The working surface portion of the contact pad actually touches the disk during normal operation.

One of the problems associated with recording heads which are in contact with the recording medium is that a substantial amount of debris is generated by the sliding action of the head against the surface of the disk. As well as being a direct result of slider-disk micro-interactions, dust and dirt from both the environment and the drive

can also accumulate on and around the contact pad region. Eventually, this particulate matter finds its way into the interface between the contact pad and the disk, leading to adverse effects such as signal modulation caused by particle induced fluctuations in the head-disk spacing, and increased wear resulting from debris entering the friction zone and scratching the working surfaces.

The problem with debris accumulation is also present in more conventional slider designs in which the head flies above the surface of the disk. By way of example, in a typical magnetic recording system, the rotation of the rigid disk causes the magnetic head or slider to become hydrodynamically lifted above the surface of the recording medium. This hydrodynamic lifting phenomena results from the flow of air produced by the rotating magnetic disk; it is this air flow which causes the head to "fly" above the disk surface. Of course, when the rotation of the magnetic disk slows or stops, the head element is deprived of its buoyancy and it lands on the surface of the disk. Repeated starting or stopping of the disk causes the recording head to be dragged across the surface of the disk over and over again during the "take-off" and "landing" phases of its flight.

The current trend in the industry is toward increasing the magnetic signal strength by lowering the slider flying height. In the conventional type of magnetic recording head described above, this means that the separation between the head and the disk is radically reduced. For instance, very low flying heights on the order of 1 to 3 microinches are becoming increasingly common. Obviously, reducing the separation between the head and the disk medium results in increased abrasive wear. Thus, in both the near-contact (flying low, e.g., at 1 to 3 microinches) and the in-contact types of recording systems, debris accumulation is a significant problem.

It should be understood that in the conventional type of magnetic recording

head which flies above the surface of the disk (i.e., near-contact recording system), the working surface which touches the disk normally comprises two or more rails having flat bottom surfaces. For example, sliders of this type are disclosed in U.S. Patent No's. 4,870,619; 4,961,121; 4,926,274; 4,709,274; and 4,709,284. To increase the hydrodynamic lifting force, many sliders have a front taper as described in U.S. Patent No. 4,939,603. Other designs include a sloping working surface. In either case, the taper and/or slope are in the vertical direction; that is, perpendicular to the disk surface. Other prior art designs include the so-called slider camber and crown -- characterized by their vertical slopes in both the longitudinal and cross directions, respectively. This latter type of design is usually selected based on considerations of smaller contact area so as to reduce the problem of stiction. The drawbacks to these designs however include the requirement for a higher take-off velocity and an increased wear rate.

What is needed then in both the near-contact and in-contact recording technologies is a slider design which is able to reduce the effect of debris accumulation so as to improve the wear rate in magnetic recording signal strength. As will be seen, the present invention comprises a magnetic head slider suitable for use in in-contact and near-contact recording systems in which the leading edge of the working surface has a narrower width as compared to the trailing edge. In several embodiments described below, the contact pad or slider rails assume either a "V" or "U" shape in the direction of flying or sliding.

Other prior art known to Applicant includes U.S. Patent 4,757,402 which discloses a slider presenting a substantially equal cross sectional area to an air film moving with the media as the head is skewed slightly relative to the oncoming air flow.

SUMMARY OF THE INVENTION

The present invention covers a magnetic recording head for reading and writing information with respect to a rotating disk medium. In one embodiment, the invented recording head includes a pad region having a working surface which contacts the recording medium during the reading/writing process. The recording head may have an integrated structure wherein a magnetic pole structure is embedded within the pad region. The pad itself has a leading edge and a trailing edge with the leading edge facing in the general direction of relative motion between the head and the medium. According to the invention, the leading edge has a narrower width than the trailing edge so as to reduce the effect of debris accumulation at the disk-head interface. A narrower leading edge allows the head to deflect oncoming debris as the head traverses the surface of the rotating magnetic medium.

In several implementations of the present invention the pad assumes a "V" or "U" shape. Shaping the pad in this manner is both advantageous to pushing the debris away from the slider as well as removing the debris away from the head by means of the hydrodynamic air flow. By reducing the amount of debris accumulated on and around the head, the present invention alleviates the prior art problems of excessive head wear and distortion of the magnetic signals.

In another embodiment, a slider for supporting a magnetic transducer comprises a body, and a plurality of rail members extending outward from the body in a direction toward the disk surface. The leading edge of each rail member faces in the direction of relative motion between the slider and the disk and has a narrower width as compared to the trailing edge. Each of the rail members includes an air-bearing surface which resides in a plane roughly parallel to the surface of the disk.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements, and in which:

Figure 1 is a perspective view of a prior art slider designed to fly at a predetermined height above the surface of a rotating magnetic disk.

Figure 2 is a perspective view of another type of prior art magnetic recording head.

Figures 3A and 3B illustrate the contact pad region of a magnetic recording head in accordance with the present invention. Figure 3A is a bottom view of the contact pad, whereas Figure 3B is a perspective view.

Figures 4A and 4B illustrate an alternative embodiment of the present invention. Figure 4A represents a bottom view, and Figure 4B is a perspective view.

Figures 5A, 5B and 5C illustrate a slider having V-shaped rail members in accordance with yet another embodiment of the present invention. Figure 5A is a bottom view, and Figures 5B and 5C are both side perspective views.

Figures 6A, 6B, and 6C illustrate bottom views of still other alternative embodiments of the present invention.

DETAILED DESCRIPTION

A magnetic recording head with improved resistance to debris accumulation is described. In the following description, numerous specific details are set forth, such as material types, shapes, processing steps, etc., in order to provide a thorough understanding of the present invention. However, it will be obvious to one of ordinary skill in the art that the invention may be practiced without these specific details. In other instances, well known elements and processing techniques have not been shown in particular detail in order to avoid unnecessarily obscuring the present invention.

With reference to Figure 1, there is shown a typical slider 10 for use in a conventional magnetic recording system. Slider 10 comprises a rectangular body onto which are formed a pair of substantially parallel rails 11 disposed along opposite sides of the slider body. Each of the rails 11 includes a surface 12 which functions as the primary load-bearing surface of the slider during normal operation. It is these surfaces 12 which alternately come into contact with, and are separated from, the disk during dwelling, starting, and stopping of the drive. Surfaces 12 are often referred to as the "air-bearing" surfaces of the slider since the rotation of the disk generates a hydrodynamic air pressure against surfaces 12; the pressure causing slider 10 to be lifted above the surface of the magnetic medium. Note further that each slider rail 11 is shown having a magnetic transducer element 14 attached to the rear or trailing edge of the slider body. At the leading edge of each rail is a tapered portion 15 which facilitates the take-off of slider 10 from the surface of the disk during spin-up.

As explained in the previous section, the lower slider flying heights which are becoming increasingly common in magnetic recording systems have lead to more

frequent interaction between the slider and disk. As a direct result, the problem of accumulation of wear debris (as well as dust and dirt from both the environment and the drive) has diminished the performance of many conventional hard disk drive systems.

Figure 2 illustrates another type of read/write head structure which also suffers from the problem of excessive debris accumulation at the head-disk interface. The integrated read/write head/flexure/conductor structure 20 shown in Figure 2 comprises an elongated, dielectric flexure body 22 having a pad region 21 disposed at one end. A magnetic pole element is embedded within pad 21 to provide flux-coupling to the magnetic underlayer of the recording medium. Pad 21 also includes a working surface 23 which is in substantially continuous sliding contact with the disk recording medium during read/write operations. The area of the working surface is usually made to be very small with a typical recording head of this type having a pad area of approximately 30 x 20 microns.

Because working surface 23 of the recording head 20 is in continuous, direct mechanical contact with the disk, accumulation of particulate matter is a significant problem. By way of example, debris accumulation often leads to undesirable magnetic signal modulation effects caused by particle-induced fluctuations in the head-disk space. An increased wear rate of the contact pad also results due to debris which enters into the friction zone between working surface 23 and the surface of the rotating disk.

The magnetic recording head of the present invention radically reduces debris accumulation at the head-disk interface by including a leading edge that has a narrower width as compared to its trailing edge. (The leading edge faces in the general direction of relative motion between the head and the recording medium.) In different embodiments the head can assume a variety of shapes: triangular (i.e., V-shaped), wedge-shaped, U-shaped, parabolic, etc. The reduction in debris

accumulation achieved by the invented head makes it ideally-suited for use in near-contact and in-contact recording systems in which the head is in frequent or continuous contact with the disk surface.

By way of illustration, Figures 3A and 3B show a contact pad 30 suitable for use in an integrated read/write head of the type described in connection with Figure 2. Contact pad 30 has a "wedge" or "V-shape" in which the leading edge 31 is much narrower than the trailing edge 33. The leading edge 31 faces in the direction of flying or sliding (parallel to the disk) with the narrow or sharp part of the shape facing toward the general direction of relative motion between the head and the medium.

Although Figures 3A and 3B show the entire slider being shaped in an overall triangular or V-shape, it should be understood that in some cases only the front portion or leading section of the contact pad structure may be shaped in this way. In other words, the essential characteristic of the invention is that the leading edge of slider be shaped so as to push away debris as the head slides across the surface of the recording medium. Note that the relative direction of motion of the recording medium is shown in Figures 3A and 3B by arrow 35. Any debris present on the surface of the recording medium is diverted away from the slider-disk interface along the sides of slider 30 in accordance with the present invention. Thus, the shape of the contact pad or slider provides a means for reducing the amount of debris being brought into the friction zone by a hydrodynamic flow.

Figures 4A and 4B show an alternative embodiment of the present invention in which contact pad 40 includes a leading edge 41 which has a parabolic or U-shape. Trailing edge 43 remains straight. The direction of relative motion between the contact pad and the medium is shown in Figures 4A and 4B by arrow 45. Once again, it is appreciated that the parabolic or U-shaped leading edge face the direction of sliding.

Note also that is makes little difference whether the curved leading edge is actually "U"-shaped, parabolic, hyperbolic, or described by some other mathematical function. It should also be understood that in the embodiments of Figures 3A, 3B, 4A, and 4B, that it may be desirable to taper the leading edges in order to improve the sliding and/or flying characteristics of the head.

With reference now to Figures 5A and 5B, there is shown a slider 50 for use in a magnetic recording system of the type in which the head flies at an extremely low height i.e., less than 3 microinches over the magnetic recording disk. In this type of recording system, the slider body alternately contacts and moves away from the surface of the disk -- achieving a stable flying height during reading/writing operations.

As can be seen, slider 50 differs from the conventional slider design shown in Figure 1 in that the rail members 52 are manufactured to have a V-shape extending from the leading to the trailing edges. The V-shape reduces debris accumulation and also enhances the hydrodynamic properties of the slider. Note that the leading edge 55 of each rail 52 is substantially narrower than the trailing edge 54. The trailing edge 54 of each rail 52 represents the portion of the slider where the transducer is normally attached. As before, the direction of air flow is the same as the general direction of relative motion between the head and the medium. The air flow is directed toward the leading edges 55 as shown by arrow 56. Basically, the front of the slider is aimed in the flying direction, with the sharp part of the V-shaped acting to push away any accumulated debris.

Although it is not shown in either Figure 5A or 5B, the leading edge portion of each rail 52 may be tapered to improve the lift-off characteristics of the slider. Figure 5C illustrates a slider 50 having rails 52 which include tapered sections 57.

Figures 6A-6C illustrate other alternative embodiments of the present invention

wherein the magnetic recording head flies above the surface of the disk. Each of the sliders of Figures 6A-6C are shown having a plurality of rail members, with each rail member providing an air-bearing surface that is approximately parallel to the surface of the disk. In each case, the leading edges of the rail members is shaped so as to reduce the problem of debris accumulation at the disk-slider interface in a manner consistent with the explanation above.

By way of example, Figure 6A illustrates a slider 60 having a pair of rails 62 extending from the body of the slider toward the surface of the disk medium. Rails 62 are disposed at opposite sides of slider 60 and are parallel to one another. Each of the rail members 62 has a leading edge 65 which is substantially narrower than the trailing edge 64. In the case of slider 60, the leading edge 65 has a "knife-edge" shape, wherein the front portion of the rail gradually tapers to a sharp point. Unlike slider 50 in Figures 5A-5C, most of the length or extent of rail members 62 is largely rectilinear in shape, -- with only the front portion being modified to reduce the problem of debris accumulation.

Similarly, in Figure 6B, slider 70 includes rail members 72 each having a leading edge 75 and trailing edge 74. In the case of slider 70, the leading edge portion of the rail members are again shaped to have a "knife-edge" profile, wherein the leading edge 75 is again narrower than the trailing edge 74. The only difference between the embodiment in 6A and that shown in 6B is that in Figure 6B, the narrower leading edge is symmetrical about the center of the rail.

Figure 6C shows a third variation of the basic concept of the present invention wherein slider 80 includes rail members 82 each having a leading edge 85 which is narrower than trailing edge 84. In the case of slider 80, leading edge 85 is "U-shaped" to deflect oncoming debris and thereby preventing it from accumulating at the slider-

disk interface. It is appreciated that the leading edge 85 of rail members 82 may also be parabolic, hyperbolic, or some other curved surface which can be represented by a mathematical function.

Practitioners in the art will further appreciate that the embodiments disclosed above do not require any major changes or complications in the basic process for manufacturing a slider. For example, in order to change a known head such as that shown in Figure 2, to include the invented designs of either Figures 3 or 4 would only require a simple modification to one of the mask designs.

Whereas many modifications and alternations of the present invention will no doubt become apparent to one having ordinary skill in the art after having read the forgoing disclosure, it is to be understood that the particular embodiments shown and described by way of illustration are in no way intended to be limiting. Therefore, reference to the details of the illustrated diagrams is not intended to limit the scope of the claims which themselves recite only those features regarded as essential to the invention.

CLAIMS

We Claim:

1. A recording head for reading and writing information with respect to a rotating disk medium, said head including a pad region having a working surface which contacts said medium during the reading/writing process, a magnetic pole structure being embedded within said pad region, said pad region having a leading edge and a trailing edge with said leading edge facing in the general direction of relative motion between said head and said medium, and wherein said leading edge has a narrower width than said trailing edge.

2. The recording head of Claim 1 wherein said pad has a V-shape, with the narrow part of said V-shape pointing in said direction.

3. The recording head of Claim 1 wherein said pad has a U-shape, with the narrow part of said U-shape pointing in said direction.

4. The recording head of Claim 1 wherein said pad has a parabolic shape, with the narrow part of said parabolic shape pointing in said direction.

5. A slider for supporting a magnetic transducer above the surface of a rotating disk medium, said slider comprising:

a body;

a plurality of rail members extending outward from said body in a direction towards

said medium, each of said rail members having a leading and a trailing edge with said leading edge facing in the general direction of relative motion between said head and said medium, and wherein said leading edge has a narrower width as compared to said trailing edge;

each of said rail members also having an air-bearing surface which is alternately brought into contact with and separated from said surface of said medium, said air-bearing surface being generally parallel to said surface of said medium.

6. The slider of Claim 5 wherein each of said rail members has a V-shape, with the narrow part of said V-shape pointing in said direction.

7. The slider of Claim 5 wherein each of said rail members has a U-shape, with the narrow part of said U-shape pointing in said direction.

8. The recording head of Claim 5 wherein each of said rail members has a parabolic shape, with the narrow part of said parabolic shape pointing in said direction.

9. The slider of Claim 5 wherein said leading edges are tapered away from said working surface to create a lifting effect to maintain said body at a predetermined height above said surface of said medium.

ABSTRACT OF THE DISCLOSURE

A magnetic recording head for reading and writing information with respect to a rotating disk medium includes a pad region having a working surface which contacts the recording medium. The pad region has a leading edge and a trailing edge with the leading edge facing in the general direction of relative motion between the head and the medium. The leading edge has a narrower width than the trailing edge so as to reduce the effect of debris accumulation at the disk-head interface. The narrower leading edge allows the head to deflect oncoming debris as the head traverses the surface of the rotating magnetic medium.

FIG 1 (PRIOR ART)

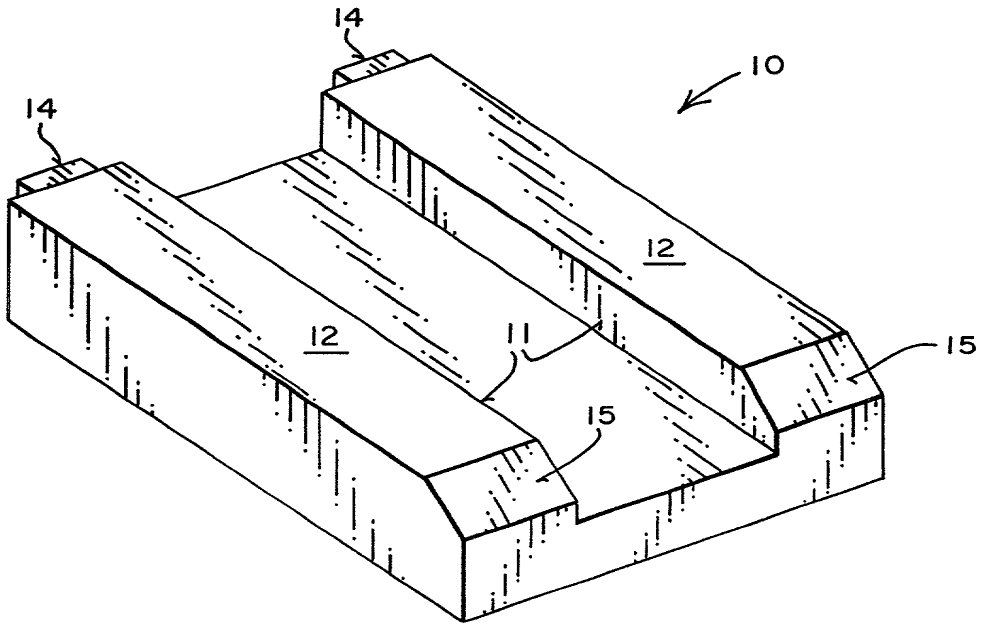


FIG 2 (PRIOR ART)

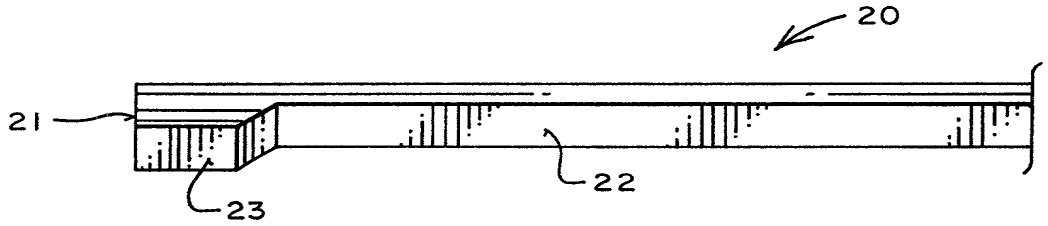


FIG 3A

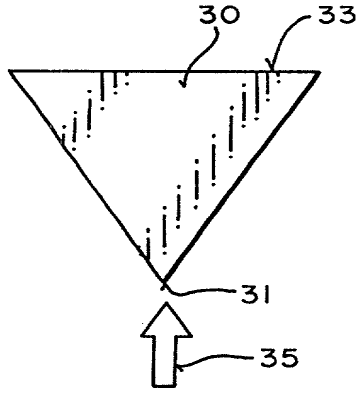


FIG 3B

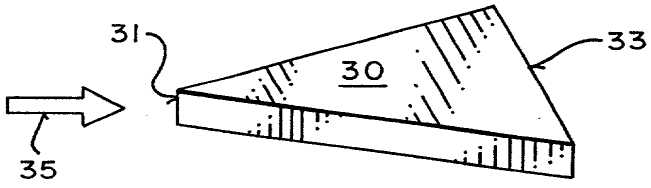


FIG 4A

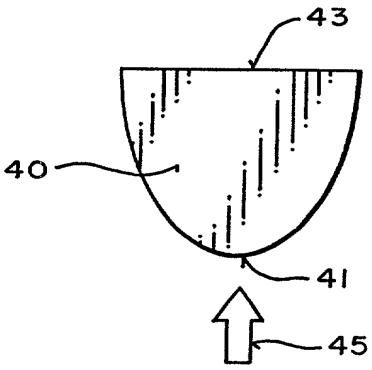


FIG 4B

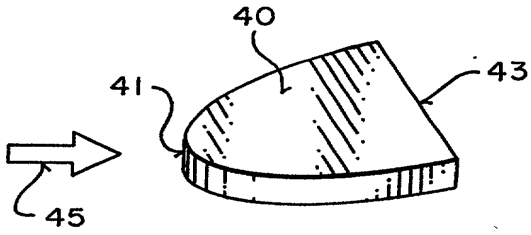


FIG 5A

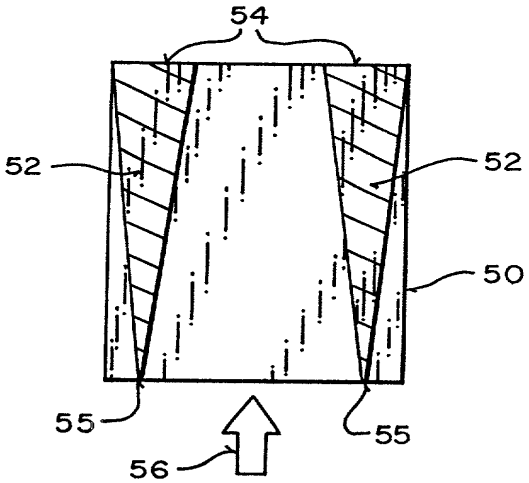


FIG 5B

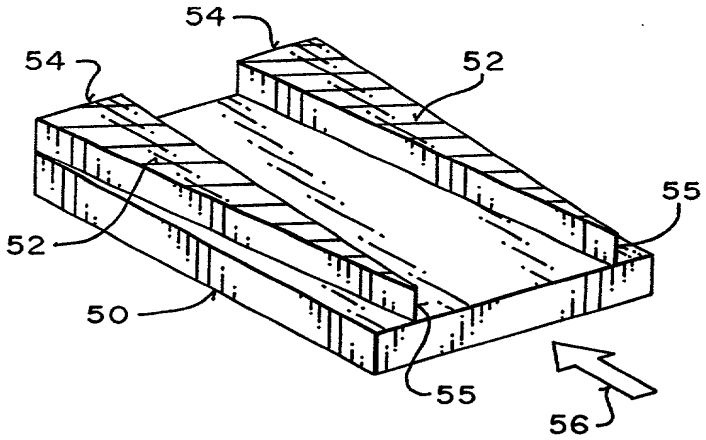


FIG 5C

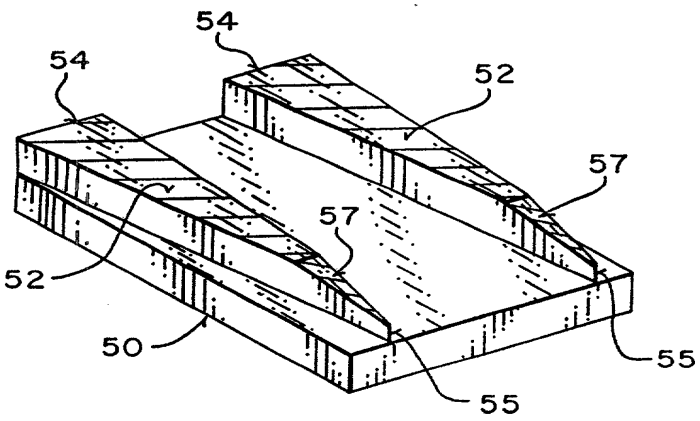


FIG __ 6A

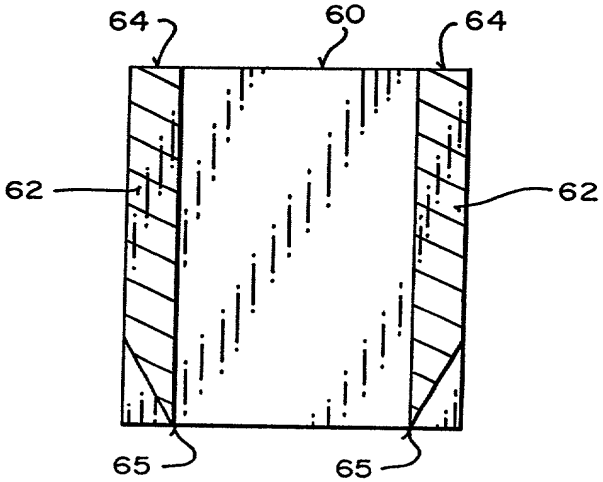


FIG __ 6B

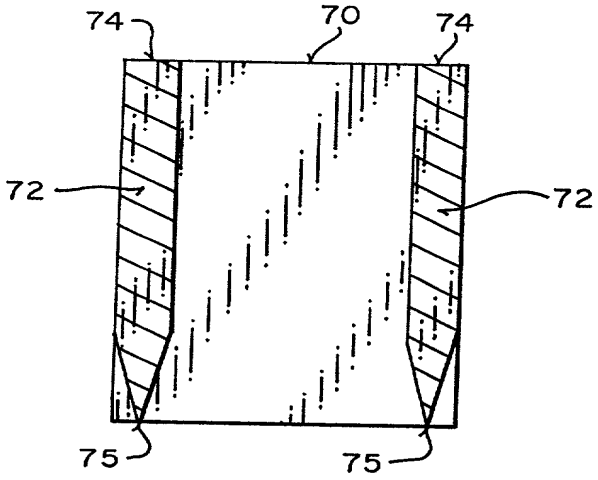
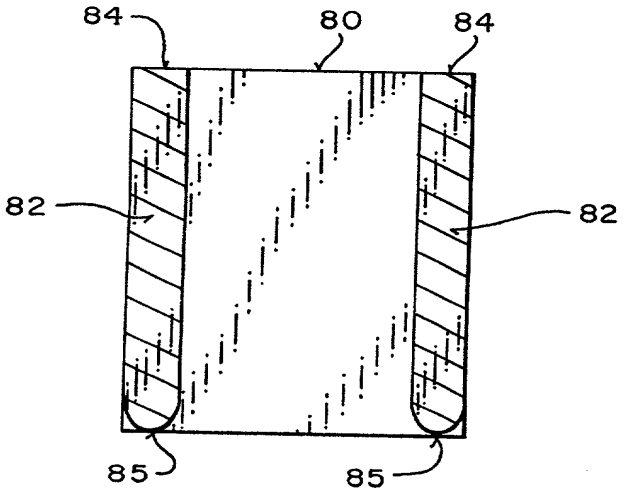


FIG __ 6C



Attorney's Docket No.: 55132.P075 Patent

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Magnetic Head Slider with Resistance to Debris Accumulation

the specification of which

___X___ is attached hereto.
_____ was filed on _____ as
Application Serial No. _____
and was amended on _____.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the same was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119, of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	Filing Date	(Status -- patented, pending, abandoned)
(Application Serial No.)	Filing Date	(Status -- patented, pending, abandoned)

I hereby appoint Paul A. Apffel, Reg. No. 35,427; Keith G. Askoff, Reg. No. 33,828; Aloysius T. C. AuYeung, Reg. No. 35,432; Bradley J. Bereznak, Reg. No. 33,474; Roger W. Blakely, Jr., Reg. No. 25,831; Jeffrey Jay Blatt, Reg. No. 30,244; Stephen D. Gross, Reg. No. 31,020; David R. Halvorson, Reg. No. 33,395; George W. Hoover, Reg. No. 32,992; Tracy L. Hurt, Reg. No. 34,188; Eric S. Hyman, Reg. No. 30,139; Stephen L. King, Reg. No. 19,180; James D. McFarland, Reg. No. 32,544; George R. Meyer, Reg. No. 35,284; Ronald W. Reagin, Reg. No. 20,340; James H. Salter, Reg. No. 35,668; James C. Scheller, Reg. No. 31,195; Ira M. Siegel, Reg. No. 28,907; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Edwin H. Taylor, Reg. No. 25,129; Lester J. Vincent, Reg. No. 31,460; Ben J. Yorks, Reg. No. 33,609; Philip K. Yu, Reg. No. 35,742; and Norman Zafman, Reg. No. 26,250; my attorneys; and Anthony C. Murabito, Reg. No. 35,295; and Edwin A. Sloane, Reg. No. 34,728; my patent agents; of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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